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LOGO
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Proposal

to the

National Science Foundation

An Evaluative Study of Modern Technology in Education

Appendix One: LOGO Memo No. 8
Appendix Two: LOGO Memo No. 27

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This proposal to the NSF describes a new phase of research planned in LOGO. Previous phases have concentrated on developing a conceptual superstructure (theories and teaching methods) and a material infra-structure (hardware and software) for a new style of using computers in education. We now want to test, to prove and to disseminate the results of our wor, which will, of course, continue along the lines of the early phases.

Part 1 is an overview of where we are and what we have to do next in the historical framework of the uses of computers for education. Parts 2 and 3 focus more on the specific content of the work planned for the next three years (1976-79).

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0. PREFACE & SUMMARY

This document describes and justifies a new phase of research by the MIT "LOGO GROUP." Previous phases have concentrated on developing a conceptual superstructure (theories and teaching methods) and a material infra-structure (hardware and software) for a new style of using computers in education. We now want to test, to prove and to disseminate the results of our work, which will, of course, continue along the lines of the early phases at the same time.

The structure of this document is as follows. For readers who are unfamiliar with our work we have attached two appendices which are publicly available as LOGO MEMO 8 ("The Uses of Technology to Enhance Education") and LOGO MEMO 27 ("Some Poetic and Social Criteria for Education Design"). The first of these is a proposal we made to the N.S.F. three years ago. It sets out the technical goals on which we have worked with almost entire success during this time. The second gives a more informal vision of a philosophy of learning. The main document has three parts:

PART 1 is an overview of were we are and what we have to do next, in the framework of an historical perspective on the uses of computers for education. This part of the document is concerned with <u>process</u> rather than specific <u>content</u>; the steps which, in our view, would have to be taken by any serious attempt to integrate the computer presence into the theory and practice of education.

We describe four major milestones in our development --

1. In the late sixties we recognized that while computers have tremendous potential for use in education, the technology of that time was marginally effective and too expensive. We consequently adopted a strategy of preparing for a future which has now arrived.

2. For the first half of the present decade we withdrew into an "ivory tower" and developed methods for using a technology which seemed futuristic to most of our colleagues engaged more directly in the day-to-day struggle to introduce computers into schools.

3. We are now standing at the third milestone. We recognize that the new technology has matured even slightly faster than we anticipated and will diffuse into schools during the next five years. We are almost alone among workers on educational technology to have concentrated on the <u>intellectual content</u> of how the new generation of computer technology can be used. We have to prove to the world that the methods we have developed are <u>feasible</u>, <u>accessible to schools</u>, <u>cost-effective</u> and <u>educationally meaningful</u>. An experiment and demonstration to this purpose is the pivotal theme of this proposal.

4. The fourth milestone will be large-scale dissemination. While this is logically contingent on the success of our proposed evaluative experiments, we argue that it would be foolish not to prepare materials for dissemination in parallel with conducting the experiments. Reasons for this include:

   (a) The experiment itself will be more convincing if it uses teaching materials which could in principle be disseminated "as is."

   (b) Time is of the essence. New technologies <u>will</u> diffuse into the schools and in the absence of available well-tried methods, untried ones will become established. And if this happens society will have to pay for one more expensive case of that bind which paradoxically places the major cost of innovation in the undoing of the old rather than the construction of the new.

PART 2 focuses more on the specific content of our actual work. It assumes familiary with the general ideas and develops a fuller perspective on a number of issues most directly relevant to the work planned over the next three years. Read together with Part 1 it reflects our increasing emphasis on practical questions related to the dynamics of dissemination:

-- cost
-- preparation of exportable materials
-- acceptability by teachers, schools, and public
-- methodology of evaluation
-- social need
-- social aspects of dissemination

PART 3 discusses the actual detail of our planned activities. The pivotal activity is an experimental class to be conducted in a public school in the Boston area in the school year 1977/78. Prerequisite activities for this during the year 1976/77 include preparation of materials; training a team to be in charge of teaching, reporting and internal evaluation; recruiting a pool of external evaluators and establishing communication with its members; establishing relations with the school system and the parents of potential students.

The preparation of materials is planned to achieve simultaneously the double purpose of serving the needs of the experiment and those of dissemination. This double purpose does not mean double work; with proper planning and attention to modularity the ideal materials for the experiment can be ideal for dissemination as well.

An integral part of the experiment is the analysis and reporting of data which will occupy at least a substantial part of the year 1978/79. We assume that new experiments, or continuation of the main experiment, will be needed at that time to delve further into problems and ideas which are sure to emerge from the experiment. It is clearly inappropriate to specify these at this stage.

We assume also that throughout the three years we shall continue to develop ideas in the style of our past work. Although we have provided for this in our budget, the cost to the N.S.F. of this part of our work has always been, and will continue to be, a very small fraction of of the real cost. The difference comes from the following sources:

- The M.I.T. Division for Study and Research in Education provides an intellectual environment in which ideas relevant to this project flourish as part of the normal academic life of faculty and students. On the average five or six faculty members of the DSRE, and many very creative students, have devoted a substantial part of their time to work which contributes directly to the LOGO project, and we can expect this number to increase in the long run.

- The DSRE has also provided direct financial support for the construction of a Children's Learning Laboratory. This facility has enormously helped the LOGO project.

- Several members, faculty and students of the Artificial Intelligence Laboratory are engaged in projects which lie in an area of overlap between LOGO and other funded activities of the A.I. Laboratory. This leads to a mutually beneficial amplification of resources.

- The LOGO group has received funding from other sources, in particular, the N.I.E. and an IBM fund for the development of ideas in computer science. We expect such support to continue in specific areas of work which are synergistic with the project described here even though they do not directly overlap it. In particular, we hope for increasing support in the following areas:

  -- <u>development of cognitive theories</u> associated with our research on LOGO and in more theoretical parts of Artificial Intelligence;

  -- <u>development of a center for work on using LOGO-like methods for</u> educational and vocational assistance to people with severe motor and communication disabilities.

1.0 Overview

1.1 History

The LOGO group at MIT is entering a new phase of a ten year process of laying the foundations for styles of uses of computers which can be expected to play a very significant role in the public schools in the nineteen-eighties. The origin of this process was the recognition in about 1968 that research on the uses of computers in education faced a strategic choice point. Experiments with computers in schools had already demonstrated certain educational benefits. The natural line of further research was to attempt to increase these benefits by exploring other modes of use of the computer. However, it soon became apparent that the cost structure of the computer industry at that time placed very severe limitations on the modes which could be considered as practical for operational use on a large scale. So the choice was between developing as far as possible within these practical limits or adopting a longer term strategy of anticipating a time in the future when other modes of use of the computer would become realistic and exploring the ways in which these new modes could be used when they did become available at acceptable cost. The LOGO Project was the consequence of choosing the long range strategy based on expectations of development in the computer industry which have turned out to have been quite conservative.

Our present situation is this: we have developed a conceptual framework and a large sample of teaching material (hardware, software

curriculum, and teaching methods) for styles of educational use of the computer very different in kind from those which have become established in operational practice in the intervening decade; pilot experiments have convinced us that these methods are now cost-effectively feasible and promise to make substantial contributions to fundamental problems in elementary, secondary and special education.

1.2 Next Step

We propose to mount an evaluative experiment with the following goals:

- To prove publicly and rigorously the conclusions we have been able to draw from clinical pilot studies.

- To provide a model of advanced educational uses of computers in a form which can be studied and/or directly copied, in whole or in part, by schools without special expertise. In particular, to prove that the methods we have developed are transferable, that teachers can be taught how to use them and that the teaching material we shall have produced by then is adequate.

- To obtain more research data bearing on a long list of questions. These include very open questions such as:

Are the benefits we have seen "novelty effects" which will wear off with more exposure? Will observers with special expertise and sensitivity be able to identify hitherto undocumented negative or positive consequences of intensive exposure of children to computers and the computer culture? We also have in mind many more focused questions about the patterns of acquisition of knowledge and skills, and about the effectiveness of specific forms of teaching and learning.

1.3 Products of Proposed Research

The pivotal activity of the project for which we hereby seek funds will be a year-long experiment in the school year 1977/78 with a mixed class of 5th and 8th grade students. The direct product of this experient will be INFORMATION in the form of a detailed set of observers' reports and psychometric measurements. But equal importance is attached to MATERIAL PRODUCTS in the form of

-- a tested, self-contained, replicable computer system
-- a set of teaching materials
-- the beginnings of a center for demonstration of advanced uses of computer science in the service of education.

The teaching materials and the computer system are being designed so as to serve simultaneously the purposes of the experiment and of subsequent dissemination. The following strategies illustrate how we plan to combine those goals.

1. Our experiment requires that the teaching materials be prepared in advance and in a sufficiently clean-cut form to define the working hypotheses being tested. Purposes of dissemination suggest preparing them in a more MODULAR FORM than would be strictly necessary for the experiment. This will allow schools and researchers to adopt parts of the material corresponding to traditional school subjects without adopting the whole.

2. In the same spirit we are designing a computer system based on powerful personal computers rather than on the overly rigid time-shared computers characteristic of the previous decade (including our own work). Consequently a school that wants to gain experience initially with just one computer station will have access to almost all the advanced computational features used in our experiment.

1.4 Form of the Main Experiment

We shall build a LOGO environment suitable for 20 students. It will be more modern, more powerful, better engineered and more futuristic in its atmosphere than any previous LOGO environment, or, indeed, probably any intellectual environment whatsoever built specifically for children.

√ The LOGO environment will be physically located in or very near a school in an urban part of the Greater Boston Area and

operated as part of the school. The choice of a school will emerge from discussions on how we can best combine our goals with somewhat different policies on curriculum of particular schools and school districts. Preliminary contacts have made it clear that there will be no difficulty in finding a sufficiently cooperative school to permit an experiment in the spirit needed to serve our purposes.

√ The student population will include all levels of prior academic performance with a numerical bias towards students with learning disabilities and low achievement scores.

√ The students will be in two classes, a fifth and an eighth grade. However, a substantial part of their work will be in common and one of the experimental goals will be to demonstrate how the LOGO environment works under "ungraded" conditions and allows much more than usual opportunity for older students to learn by teaching the younger ones. The experimental class will be a full time, year long, integrated learning experience with as little accent as possible on the distinction between "computer work" and "non-computer work." We will not artificially impose the use of the computer on parts of the work for which it does not seem natural; on the other hand it will be available at all times for use when wanted, even when the particular use has no specific "justification."

√ The curriculum for the class will be developed in conjunction

with the school staff so as to combine as organically as possible whatever the school perceives as essential content material with our own approach to content in the core subjects. In some sensitive areas, particularly mathematics, our own highly computer-oriented courses cover much of the key content required by schools; and even when we do not cover certain topics directly we prepare the way so thoroughly that the work of filling in should not be onerous for students or staff. This is equally true of the formal parts of work on language.

In other areas, for example, in biology, our curriculum material does not explicitly overlap to any large extent the topics normally taught in school. On the other hand, in these areas schools are not as rigidly committed to particular content and seem ready to agree that our material serves as well as theirs as an introduction to scientific method.

1.5 A Window on the Computer Culture

Our proposed experiment serves another important purpose at no extra cost. This is giving the education community a "window" on potentially relevant advanced aspects of modern computer science. There exists a very large and increasing gap between the image of computation easily obtainable by an educator, say a high school teacher, and the real content of computation as practiced in advanced centers of research and development.

Take as an example the concept of a programming language. The conceptual gap between, say, BASIC or APL and the languages used, for example, in Artificial Intelligence research is growing exponentially. Now it might or might not be true that languages of the BASIC/APL/FORTRAN family are the proper languages for educational use. We think not. But the more important part of our position on this issue is that, irrespective of what the right decision may be, it should not be made by default, merely because interested educators have no realistic access to seeing more than one kind of programming language at work in an educational context. Our experiment will provide for the first time the opportunity for many educators to observe a language very different from members of the BASIC/FORTRAN/APL family. And LOGO, especially in the form in which it will be used for this experiment, is not merely "another rival language." The proper way to look at it is as a large and extensible collection of <u>features</u> of advanced languages; it is to these features of computation rather than to the particular aggregate of them called LOGO that we wish to draw the attention of educators.

In this sense our experiment provides a window into a wider computer culture. Advanced languages are in fact only one of the many facets of the spirit of modern computation which are reflected in the design of our experimental system.

To facilitate this function we should set up the school installation in such a way as to permit use, outside of school hours, by teachers and others looking for a "hands-on" experience with a modern computer facility. It is obvious to us that the availability of such centers would increase very substantially the level of sophistication of decision making about computers in education.

1.6 Observation-Description and Evaluation

Some scientific experiments provide a yes/no answer to a single, crisply posed question. Others bring in a large quantity of data which will be analyzed for many years ahead and used in many ways which have not been identified in advance. The experiment we propose to do has many dimensions, some of which are closer to each of these two paradigms.

Dimensions which allow yes/no or quantitative answers include some very simple predictions which we see as a bold challenge to the policy makers in education, for example:

-- Expectation 1: the scholastically unsuccessful group among the students will advance by several grade levels on standard achievement tests in mathematics and language. We shall, of course, confirm the significance of any such observation by comparison with a control group matched on a series of variables set up before the outset of the experiment.

Other expectations are essentially more qualitative:

-- Expectation 2: observers will agree that the student in the experiment not only learned more than in a traditional class, but learned it in a more articulate, richer, more integrated way.

Confirming or disconfirming these expectations does not raise complex theoretical issues. Expectation #1 is a matter for standard statistical treatment. Expectation #2 falls within the range of topics about which every educator frequently makes personal judgements.

More complex issues arise when we look at the dynamics of the many forms of learning and growing that will take place in our environment

-- Expectation 3: students will develop, or adapt concepts and metaphors derived from computers and use them not only as intellectual tools in the construction of models of such things as "number" and "theory" but also in elaborating models of their own cognitive processes. This will in turn have an impact on their styles of learning and problem-solving.

-- Expectation 4: the use of computer metaphors by children will have effects beyond what is normally classed as "cognitive skill". We expect it will influence their language, imagery, games, social interactions, relationships, etc..

Acquiring data bearing on Expectations #3 and #4 is a more complex and subtle endeavor. It needs observers with special sensitivity to explore models that children use when thinking, when learning, when playing; with sensitivity to depth psychology and with sufficient sensitivity to the substance and to the implications of computer ideas to recognize the diverse forms these may take when assimilated by our students. The nature of our material will allow us to take steps towards formalizing better than has been done before concepts such as "richer" and "integrated" used in making intuitive judgments.

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Our laboratory is in a unique position to pursue this kind of integration and to assemble a powerful team of collaborators. We owe this to a long period in which we have served as a milieu which encouraged working towards integrating these streams of psychological thought. An example is the way in which we have over the years mediated exchanges between workers from Piaget's Institute and other centers of Cognitive Psychology with researchers (in our laboratory and elsewhere) from the world of computers. Another example is the interaction between members of our group and psycho-analytic thinking.

So far we've spoken only about observation of the responses of members of the class. Although this is clearly the primary goal of the experiment, we feel it very important to observe and evaluate the effect of this experiment on at least two other groups: the parents of the children and a sample of members of a broad community of educators.

With the wisdom of hindsight, it seems clear now that the difficulties encountered by such curriculum reform as the New Math were aggravated by the reactions of parents and teachers to the new things the children were learning. The parents often perceived the new math as strange, as alien to them; they often responded to it defensively. Children learning the New Math at

school were thus given conflicting signals about it at home, messages that tended to reduce it in value and seriousness. It also now seems clear that children were given equally conflicting messages at school. The planners of the new curriculum did not have the necessary deep understanding of what the new concepts meant to its teachers, teachers who were often quickly indoctrinated and thus could hardly convey the spirit as well as the formalism of the new curriculum.

We thus begin our study highly concerned with the necessity of understanding and working with parents and teachers. We know that we shall not be able to understand the dynamics of the development of our class without knowing more about how parents perceive the experiences of their children. Already in the practice of our pilot studies over the past years, we have developed ways of bringing parents into our learning environment. For example, children are encouraged to bring their parents into the learning lab, to explain their work to their parents, and even to teach them how to work with the machines. Parents learn to write simple programs, reducing their sense of alienation from the children's experience and almost always improving the child's relationship with his work, turning it into something shareable and therefore more positive. In the new phase of our work we shall greatly extend our work with parents as a way of understanding how the child's experience with us is reflected in his relationship at home and how this reflection in turn affects his work with us. Our work with parents thus

not only improves the chances for the success of our projects, but also will give us some data about the social construction of computer based learning and of the ways in which the computer is gradually integrating itself into the culture.

We do not anticipate difficulties with the teachers in our 1977/78 experiment. All the teachers will have an understanding and appreciation of the spirit as well as the letter, the meaning as well as the form, of our ideas. To insure this we shall work intensively during the pre-experimental year with a group of teachers, some of whom will go on to participate in the experimental class. This experience will also serve as a workshop in which we can learn how to anticipate the problems that must arise when our methods are disseminated beyond our protected experimental setting. This study of the reaction of teachers will continue during our experimental period when we shall work with groups of teachers in our school seting who have known the children in our experiment, and who continue to have some interaction with them. From this collaboration we hope to draw information which can be extrapolated to the larger community of educators whose reaction to computers in general, and to specific ways of using them, must be understood as a basis for planning for the widespread integration of computers in education.

We must stress here that the spirit in which we investigate the reactions to the computer presence is not a passive one in

which we study an impact, but a dynamic interventionist one in which we see ourselves as actively shaping the nature of that presence itself. An example of this kind of intervention is our creation of the turtle as a totally new manifestation of a computer presence. In contrast with the image of the computer as teaching machine, the turtle image not only pleases in itself, but contributes, as we have seen from widespread reaction in the media, to an acceptance of the computer itself. Thus we are fundamentally concerned with creating a kind of computer presence which is compatible with our culture, one which is resonant with people's sense of who they are and who they want to be. If we do not proceed with sensitivity to these questions, which are ultimately questions of psychology, politics and poetics, as well (if one can make that distinction) as being questions of education, the work that we are doing, the ideas that are being created, will not in Dewey's phrase, take root in the sub-soil of people's minds.

2.0 Aspects of the LOGO Learning Environment

In order to understand the concept of learning environment that has grown with our project the reader might begin with the specific descriptions of our work and our vision contained in the appendices. Our concept of a learning environment is highly dynamic and would be much better appreciated by seeing the films which we loan on request. But even film falls far short of conveying the power of what it feels like to be drawn into a relationship with our computers. Their holding power can only be understood experientially; we encourage a visit to our laboratory, an opportunity "to play child," engage oneself with the computer as a child might.

Having said this, we now assume that the reader has read the papers and watched the films or visited the Lab and that we can talk about aspects of LOGO on the assumption of some shared knowledge. Some of the specific aspects of LOGO that we wish to discuss are conceptually simple and easily stand alone by themselves; in particular, the time is now ripe to give more attention to cost and cost-effectiveness. There are, however, other more complex issues which involve disengaging the multiple strands of our eight year long LOGO experience. The disengagement is conceptual and practical. We need to separate the strands conceptually to explain them to others and study them ourselves. We need to disengage them practically for reasons connected with the fact that LOGO is beginning to move into the world of educational practice.

The fabric that we have woven in the LOGO project can be best

appreciated and used as a whole -- an integrated education system. Some schools will do this. However, it is to be expected that the first major "appropriation" of LOGO into educational practice will be piecemeal. It is important for us to maintain as far as possible the power of the initial "integral" conception while being flexible to the needs of schools and researchers who are unable or unwilling to adopt the entire system. Thus we proceed now to a discussion of some facets of LOGO which can be factored out both conceptually and practically.

We shall relate each of these separable facets to practical issues of cost and acceptability by schools and to our 1977/78 experiment. The experiment itself, of course, bears most directly on LOGO taken as a whole. But the experiment is planned with a view to elucidating the separate facets; the teaching material we are preparing for it is modularly conceived; and the reporting will take account of the needs of people interested in particular facets.

2.1 What is LOGO?

There is a systematic ambiguity about the use of the word "LOGO." Sometimes it is used narrowly to be the name of a particular programming language. Sometimes it is used as the name of an evolving family of programming languages of which the version to be used in the 1977/78 experiment will be an advanced version very different from the ancestral language of that name. And finally, "LOGO" is

used very broadly to refer to the philosophy of education which gave birth to the programming language LOGO.

This confusion is unfortunate and should be resolved possibly by keeping the name LOGO for the language and inventing a new name for the philosophy. We do not have time to do that at this moment and so will continue the ambiguity in this document. We make the convention that the word "LOGO" has the broader sense except when the context makes it clear that we are referring only to the language. More precisely LOGO will be used to refer to the philosophy and practice of education associated with the MIT LOGO group and expressed in part in the papers appended to this proposal.

2.2 The LOGO World

A salient feature of the LOGO Learning Environment is the way kids use the computer to exert powerful control over real-world, visible or audible processes. They cause Mechanical Turtles to crawl on the floor, they cause Light Turtles to draw pictures on a screen faster than the eye can follow, they cause music and speech to emerge from computer driven speakers and so, in principle, *ad infinitum*.

All this is part of creating a computer culture. It is not merely there to "motivate" little kids, but to create, from the outset, a perception of the computer and a relationship with it. In the LOGO world the computer is seen as powerful and as personal.

It will do things for you that you want done. Moreover, the things it can do for you are not chosen merely because they are noisy or fun or because we like them. They are chosen because they lend themselves to mediating relationships which we believe to be the tain kind of computer sub-culture which we have decided is the richest, most human and educationally best of the several existant sub-cultures. This is the culture associated with the most advanced sectors of the larger computer world; for example, it is the dominant culture of all major Artificial Intelligence Laboratories.

Here are two very simple examples of how the modest turtle can mediate a relationship with such an impressive culture.

EXAMPLE 1. The turtle encourages and enables the beginner to identify with, and so to anthropomorphize, computational processes.

This immediately establishes a cultural bond with programmers and theoreticians in the center of the computer culture.

EXAMPLE 2. Writing programs in LOGO is seen from the beginning as teaching the computer new commands. You, the beginner, can actually change and extend the given computer language!

EXAMPLE 3. Neither of these perceptions is typical of beginners in most introductory programming environments (though, taken by themselves, they are not quite unique to the LOGO-like environments).

2.3 LOGO as an Effective Route to Programming

A few hours of watching children in our Laboratory convinces most observers that LOGO provides an extraordinarily effective approach to the introductory teaching of fundamental elements of programming and elementary computer science. In particular, we are convinced that an average high school student will reach any reasonable criterion of programming competence by working in a LOGO environment after a small fraction of the time he would need in, for example, a typical school BASIC environment. Thus, although the use of LOGO requires slightly more costly hardware, the final cost of achieving competence is less.

The advantage of LOGO is greater still when we consider either the more academically successful students or the least academically successful. To see why this is so we recall that LOGO has the advantage over most programming environments of opening many more doors into interesting programming projects. For the advanced student the richness of projects connects with intellectually substantive areas. For the "backward" student the projects connect with simple intuitively meaningful activities and this often makes the difference between being able to learn programming and not being able to learn it at all, irrespective of how much time is available. Other components of the relative advantage of LOGO come from its greater expressivity, mnemonic characteristics and compatibility with linguistic and cognitive structures.

The reactions of these different categories of beginner will be thoroughly documented in the first weeks of our 1977/78 class. After these weeks the members will, of course, no longer be beginners, but these initial observations, if well done, may form the most detailed investigation to date of how a group of people of any age began its formal interaction with a rich and varied computer culture. It will be fascinating to see how their initial reactions correlate with what they do later.

We mention finally that the merits of LOGO as a route into programming are not special to young beginners; it is ideal for almost all non-specialists such as teachers, executives, psychologists, etc. Now that graphics is becoming widely available at (almost) reasonable cost one can expect a rapid increase in the number of decisions to adopt LOGO for this purpose.

2.4 LOGO as Math-Therapy

People often express the fear that computers will undermine mathematical competence (because "kids will rely on machines" instead of "using their own knowledge"). Some uses of the computer might justifiably invite the complaint. Ours do not. On the contrary we have seen a small but highly compelling set of examples of intransigently anti-mathematical children who allowed themselves to be seduced by the LOGO computer into relating to numbers in a friendly and personally warm spirit.

The unusual phrase "relating to numbers" reflects a set of observations and a theory of one major cause of mathematical incompetence. This is that mathematical inability is often associated with a "refusal to allow numbers into one's head," and an extreme discomfort when a number does force its way in. Deciding which is cause and which is effect is less important (for this discussion) than the fact that they mutually support one another: bad feelings towards numbers lead to increasing incompetence at dealing with them and so to even worse feelings of antagonism and tension.

In LOGO we often arrange the initial approach to the computer so that a student who prefers to avoid numbers can still do interesting work but using them brings a visibly worth-while pay-off. For example, a turtle might be set up to accept commands like

FORWARD and RIGHT-TURN with or without numerical inputs. Although it can be fully controlled without numbers, doing so is a nuisance and our experience shows that sooner or later even quite matho-phobic children will come to want, almost despite themselves, to use numbers.

Once a child has let himself enjoy working with numbers he will progressively experiment more freely with their use and very soon begin to build up his stock of arithmetical knowledge and with it an increasing sense of comfort with numerical work. The therapeutic goal of working with the computer is largely served once this change of relationship has taken root: the child is now on his way back into the mainstream of mathematical learning.

The detailed dynamics of this process needs further study. But the central point seems clear and compelling enough to warrant this statement as a working hypothesis:

> Temporary exposure to computers can play a powerful "therapeutic" role in assisting a child out of a vicious circle of self-perpetuating mathematical incompetence.

The obvious questions that arise are:

- -- permanence: does the effect last?
- -- feasibility: can school staff do it?

-- cost: how expensive?

We are very sure of positive answers for the first two and will obtain much deeper knowledge from observation of the "non-mathematical" sub-group of our 1977/78 class. To the third question we reply with some rough and ready numbers:

* We think of twenty "terminal hours" as sufficient to obtain significant effects of this kind (though, of course, more is better and sometimes shorter exposures trigger quite deep reactions).

* The cost per terminal hour of a well managed and well designed system bought at current prices should be between 50¢ and $1. Divide by two to guess costs in three years from now. So let's say $20 per child as a high estimate for computer costs for a "therapeutic LOGO course."

* With what should we compare this for cost-effectiveness? Perhaps a good yard-stick is the cost of other forms of remedial teaching (tutoring, counselling, etc.). The LOGO course is comparable in cost to, say, three hours of time of a specialist, or twenty hours in a small class. Since the LOGO course also requires the participation of an instructor, a realistic calculation for cost-effectiveness is the comparison of, for example, one term of participation in a small remedial class (say 6 children and one teacher) using LOGO , as against two terms with a teacher without LOGO. These are comparable in cost; our prediction is that the LOGO option would be many times more effective as measured, for example, by the number of students who will no longer need remedial teaching.

2.4.1 LOGO as Cognitive Therapy in General

What is true for mathematics is true, though not quite as obviously, for other kinds of learning disability. There are some well documented cases of autistic children responding remarkably. We have seen the discovery that "I can do math!" cause a total change in a child's image of himself as a learner, as an intellectual agent. It is not difficult to understand the therapeutic effects that can come with such a change of self-perception.

2.4.2 LOGO as a Learning and Vocational Environment for People with Severe Physical Handicaps

We have pursued this idea which was sketched in the appended previous proposal and have, as one might easily guess, found that an almost miraculous change of life perspective can be produced for many people who suffer from Cerebral Palsy. Of all these facets of LOGO, this is probably by far the area of most favorable cost-effectiveness.

2.5 LOGO as a New New Math

We should distinguish between the use of a small dose of LOGO as matho-therapy and the introduction of a new mathematics curriculum. The former needs less commitment and is likely to reach large scale acceptance in a much shorter time. But the case is strong for a new "New Math" based on computer ideas as illustrated especially by the Turtle theme in LOGO. Negative experience with the old New Math is not logically relevant; indeed since our proposed New Math goes in exactly the opposite direction than the old New Math, the back-lash should be in our favor. The point is that the old one moved in the direction of pure mathematics, while ours is the first serious proposal to make a coherent applied mathematics for children. It is also relevant that a computer-oriented math would be in tune with a larger movement in society namely the diffusion of computers, and so have more social reality for ordinary people than, say, set theory.

This kind of argument cannot prevail in the absence of very clean-cut demonstration, which we expect to emerge loud and clear from the 1977/78 experiment.

A word about costs. We could argue immediate cost-effectiveness for the therapeutic application because it is short-termed and because remedial teaching is expensive in any case. But to transform the entire normal school mathematics experience is an enterprise of a different scale. To do so in a thorough way would certainly add $25 per year to the cost per child, perhaps even $50. It is not

our function to decide if schools can afford that. But we do think that a large number would do so if they were truly convinced of the effectiveness of what they would buy. Actually we believe, and would like to prove that with half the time presently devoted to mathematics one could actually achieve true learning which is not now being achieved in any acceptable sense even with the whole time now devoted. So if costs are calculated rationally this ought to come out ahead and all schools would accept our position (on the assumption, still, of compelling proof).

The logic and the accounting of all this is too complicated for us. But all we ask is to be able to make the demonstration and if only 10% of schools follow the "rational" course, that is still a large number of children.

2.6 LOGO as a Basis for a Unified Math/Science Curriculum

2.7 LOGO as Teaching Thinking

2.8 LOGO as a New Linguistics

2.9 LOGO as a Total New Conception of School

Although we have referred to these terms throughout this text, some of our views on these very relevant facets are expressed in more detail in the appendices.

3.0 Design for a School

In the following pages we sketch a preliminary draft of the anticipated life of our experimental learning environment (§3.1 - §3.4) and of the organization of the pre-experimental year (§3.5). We expect all the plans for the experiment to be revised and developed during the pre-experimental year; our present goal is not to specify details but to show that we have a sufficient body of ideas to justify an experiment on this scale and to convey a deeper sense of the intended spirit of the experiment.

3.1 The Computer in Language Skills -- An Aspect of the Computer Culture

We shall turn, in a moment, to discuss curricula on the level of what theorems are taught in which school term. But first let us touch on an equally important part of what we want the students to learn. This is an attitude to computers which we see as central to the computer culture into which they will be initiated during the experimental year as we believe everyone will before the following decade is ended.

This attitude consists of seeing the computer as a very <u>powerful</u> device, but also as a very <u>personal</u> and <u>ordinary</u> thing: not something to be used by special people (programmers or computer scientists) or on specially defined occasions (such as math classes) but quite casually much as everyone who can write uses paper and pencil. For example, it should be easy and seem natural for a student to use the computer as an aide-memoire to recall dates,

birthdays, telephone numbers, trivia of all sorts; it should be the simplest communication channel to pass a message to a classmate or request a book; it should be used to write, edit, print-out and file away personal letters, notes on projects and, of course, more formal pieces of writing such as reports and essays. It should serve the same purpose for music and for drawing.

Let us dwell on the use of the computer as a medium for writing. First we note some material pre-requisites for this to be done acceptably. The simplest of these is that the mechanics of typing and of operating the computer system should not be an obstacle. This in turn implies that the computer time available for the student be sufficient to justify spending some of it on the "capital investment" of acquiring such skills, which are no fun in themselves. It also implies that the computer system should be easy to learn,(preferably very incrementally)and should be built on sound human engineering principles (e.g. it should react fast so that the user does not have to sit through long seconds of distracting silence or clattering teletypewriting).

Suppose that these conditions are satisfied. The student works at a very fast, very clear CRT display, using a much better than average text-editing system which he has mastered sufficiently

to make writing at the computer at least as comfortable as writing with pen on paper. So what? What good does this do?

We have not yet been able to do this experiment with a group of students of the age level planned for this experiment, partly because acquiring the routine skills did not seem worth-while for students whose access to the computer was too limited to provide a sufficient pay-off for the trouble even of learning to type well enough. But we have observed the reactions of college students to a good computer text editor. The effect on writing habits of free access to such a system is unambiguous: they write more and they write better, with more polishing and editing. We do not claim to understand all the factors responsible for this: but one large and obvious factor is easy to understand and should apply even more powerfully to the younger students in our experiment.

The conceptual component of revising or editing a piece of writing can be exciting; the mechanical component of actually changing the physical words on physical paper is messy and frustrating even if one has an adult's skill at using the pen and a secretary to re-type corrected drafts. The mechanics of editing quickly becomes intolerable if one has to make clean copy by hand and especially so if one writes as laboriously as a typical fifth grader (who is the one who really needs a secretary!). Our very confident prediction is that if the computer can be used to make writing and

editing easy (which it can and will do in our experiment) the students will quickly increase the work they are willing to do on their writing. They will thereby improve not only the particular final texts to which they devote this work but also their own writing skills, so that by the end of the year their first drafts will be enormously better than the texts they were accustomed to hand in as final products.

It may be important for all this to work that the student comes (as most surely he will) to _like_ the computer and it is possible that the use of the machine in very different kinds of work will induce transfer of positive feelings from one domain to another. For example, a student who likes mathematics and does it well, may come to like the computer because he perceives it as a mathematical object and then comes to like writing more than before because it is done with a computer. And, of course, the process might also go in the opposite direction, bringing someone who loves words and despises mathematics to see these two domains as less separate than he did before. We have reason to believe that the consequence is to like mathematics more rather than language less.

3.2 The Technological Fix Bug-a-boo

There is a tacit suggestion in §3.1 that providing students with an appropriate material system is the proper way to improve language skills rather than by developing better courses in creative writing or whatever. Some people will cry out against this "technological fix," as they do against so many other technical solutions to social problems. But that would be unfair, for our fix derives its meaning and its power from the social and cultural aspects that go with the material one. The text editing system is not a mere machine. It is a language, a culture, a set of relations between writing and other domains.

We do believe in technological fixes to this extent: if one must make a choice of relative values, it is much more important educationally to provide facilities (such as the hypothetical good text-editing system; such as LOGO and Turtle Graphics) than to work out curricula and behavioral objectives. With such facilities the student can do a great deal of work and make a great deal of progress with just a little input from adult instructors. Without them the self-generated action of students with the slightest failure of motivation becomes sluggish or impossible, and learning stalls except when pushed by a teacher wielding a carrot or a whip.

3.3 Curriculum

Despite the previous remark we have elaborated an almost uncomfortably dense curriculum for our experimental class. The

following outlines are, of course, very provisional. They deal, moreover, only with those subjects which we now know how to change rather profoundly as a result of the computer presence. There will also be work on social studies, history, etc. which will no doubt draw on the computer facility since it will be there, but we do not feel that it is necessary for a definition of an experiment to spell out here how that might happen.

3.3.1 Mathematics

The organizing theme is Turtle Geometry.

FIRST QUARTER: fundamental skills through projects like making walking figures (men and animals), and abstract graphics. This covers the following topics:

Programming Topics: fundamentals of LOGO, procedures and sub-procedures, simple recursion The Little Man Semantic Model, Dots and Quotes ("Variables"), Lists.

Turtle Geometry: fundamentals -- FORWARD, BACK, RIGHT, LEFT, SPIN, MOVE, STATE, XCOR, YCOR, HEADING, Naming Points for Global References.
theoretical ideas -- TOTAL TURTLE TRIP THEOREM, SIMILARITY THEOREM, POLY THEOREMS, GROUP OF RIGID TRANSFORMATION.

Numbers: use of decimals, multiplication in scaling, orders of magnitude and estimation.

Heuristics: systematic treatment of heuristics of constructing simple programs, bug types, "Problem Scene" theory of word problem analysis

SECOND QUARTER:

a. Gridland/Germland/LOGOMECIA, etc. (Merges with Science Topic on Movement in Fields). Sensing Turtles.

b. <u>Number</u>: Random Statistical Concepts, especially Fractiles. Concepts of proportion, linearity, rates of growth.

Advanced Students Only:

c. Algorithms for Search, Recognition, Connectivity, etc. in Gridland; connectivity; curvature; simple line integrals; general maze algorithms.

THIRD QUARTER:

a. Three dimensional geometry. Projects like: airplane or space-craft simulator; architecture design programs.

b. <u>Number</u>: heuristics and procedures for fast mental arithmetic developed and used as computer procedures and as "people procedures." Acquisition of competence in executing latter.

Advanced Students Only:

c. Stereograms; generation of biological forms (snails, horns, etc.).

FOURTH QUARTER:

a. Individual Projects.

b. <u>Number</u>: Student generated teaching programs designed to fill gaps in knowledge required by school for next year.

3.3.2 Language

FIRST QUARTER:

a. Introduction to Text Editor and associated computer aids to writing. Writing projects, with emphasis at first on projects involving small quantities of text and much use of font design and manipulation, lay-out, etc. As typing improves projects can become wordier.

Acquisition of typing skill.

Use of filing system for personal information, sending messages, etc.

b. Reading and discussion of literature.

SECOND QUARTER:

a. Writing Projects continue.

b. Generative grammar introduced through programming sentence generators and simple interactive programs. Deep structure, transformations, deletion rules, etc.

For advanced students: simple parsing programs.

c. Aesthetics seminar on computer generated art ("concrete poetry," graphics, music).

THIRD QUARTER:

a. Writing and Reading.

b. Pattern matching and transformations through writing and/or modifying Weizenbaum DOCTOR programs.

Beginning phonetics and spelling.

FOURTH QUARTER:

a. Project to write and test a teaching program in some area of language.

b. Write report on the year.

3.3.3 Science

The science topics emphasize observation of natural phenomena in areas which allow connection with theoretical models related to the on-going work in programming and in mathematics.

FIRST QUARTER:	"Wheels and Walking." Study of vehicles, animals and people through naked eye observation, photography, theory construction and computer simulation.
SECOND QUARTER:	Tropisms, orientation, etc., in simple animals and plants. Observation using microscope. Attempt to formulate theories in the form of algorithms in a stimulus field. Simulation of some algorithms. Understanding interplay of "stochastic" and "deterministic."
	At some time, beginning of study of bodies moving in gravitational fields.

THIRD QUARTER AND FOURTH QUARTER:

Astrogation in context of learning to drive a space ship simulator, play space-war, etc.

Alternative projects in color science using computer color display; in sound using computer for signal analysis and detection, for music generation, etc. and other topics related to sensation.

3.3.4 Learning Skills

The "curriculum" will follow the following cycle with a number of skills starting with three-ball juggling because we understand it very well:

- ≈ Subset of students are taught the skill.
- ≈ These students teach others, keeping notes and writing a report on effectiveness of variants of teaching procedure.
- ≈ Students work in a project spirit on inventing extensions of skill and in inventing and testing plans for describing learning, and teaching. (For example, in juggling, extensions might be: juggle 4 balls; juggle apples and eat them while juggling; juggle while performing another act such as balancing or riding a unicycle.

A less physical skill which we also understand in the same spirit is expertise at classes of puzzles, for example, topological string puzzles.

The purpose of this work is to encourage "generalization" or "transfer" of the ways of thinking acquired in the LOGO work by applying them explicitly to apparently very different areas of activity. This intention will be explained to the students as well as the highly tentative nature of the theory on which it is based.

3.4 Organization of Work for the Experimental Class

The responsibility for actual teaching will be entrusted to two teachers, primarily responsible for the 5th and 8th grade groups respectively. These teachers will be assisted by members of the MIT LOGO group. They will have been trained during the previous year as part of the working group described below (§3.5).

In principle teaching material will have been produced during the year 1976/77. However, a writer/teacher will be part of the team with the responsibility to revise material or generate new material in response to the progress of the class.

A panel of eminent external evaluators will be intellectually in charge of determining evaluation procedures. A half-time staff member will be charged with carrying out their decisions. In addition several experts in different aspects of psychological and educational observation will study and report on the progress of the class (See §3.5).

An academic seminar at MIT under the direction of Seymour Papert will be entirely devoted to following and discussing the progress of the experiment.

3.5 Organization of Work During the Pre-Experimental Year

The tasks for the year 1976/77 are as follows:

TASK 1

Create a working and planning group of people who will constitute the nucleus of the team of teachers and internal observers during the experimental year. It is essential for this group to include a rather large range of skills including teaching, clinical and cognitive studies of children, depth psychology, educational evaluation and, of course, the ideas and methods of the LOGO group. It is also essential that the group work together intimately enough and over a long enough period to establish firm lines of communication and understanding. The current plan is this: irrespective of whether this project receives funds in time a nucleus of the group will begin work in the fall of 1976. So far we have found (outside the MIT group) three highly qualified people with expertise respectively in:

(1) clinical psychology/special education

(2) clinical psychology/depth psychology/sociology

(3) science/elementary school teaching

all of whom will be able to give substantial amounts of time for several months irrespective of NSF funding and will, in principle, be available for up to half their time if funding is available.

Seymour Papert will make the operation of this group (including planning for the year 1977/78) his major research commitment

during the academic year and, to facilitate the work, reduce his teaching load during the fall to a fraction of one course.

Other members of the LOGO group will participate to various degrees.

TASK 2

Prepare written teaching material: This task will need a full-time teacher/writer who will participate in the working group, write materials and coordinate other members of the group who can contribute written material. This task will be helped by the fact that some material suitable for the class is now being written by members of the LOGO group.

TASK 3

Work on the computer system, including the text-editor: This will be a very serious programming task and will require two full-time programmers as well as part-time help by students and other members of the LOGO group.

TASK 4

Prepare the hardware for the experimental period: We propose to put out a request for bids for this to be supplied on a turn-key basis.

TASK 5

Negotiate with school systems about the site of the experimental class: A decision must be made by December, 1976. Once made, we must begin to establish a close relationship with the teachers, the

students and the parents so as to build the trust needed for the conduct of such an experiment. Our tentative plan is to establish by early spring, 1977, a small public access/children's museum-type of LOGO center in or near the school so that everyone concerned can get to know at first hand what we are trying to do before we even ask for volunteers for the experimental class.

TASK 6

Explore contacts with a panel of external evaluators: We hope the experiment will appear sufficiently exciting and novel to draw some of the leading people in the field of evaluation. It is obviously necessary for the creditibility of the experiment that we have a representative panel of highly respected people. It will also be of immense value to our scientific goals to have feed-back from evaluation with different backgrounds and theoretical approaches.